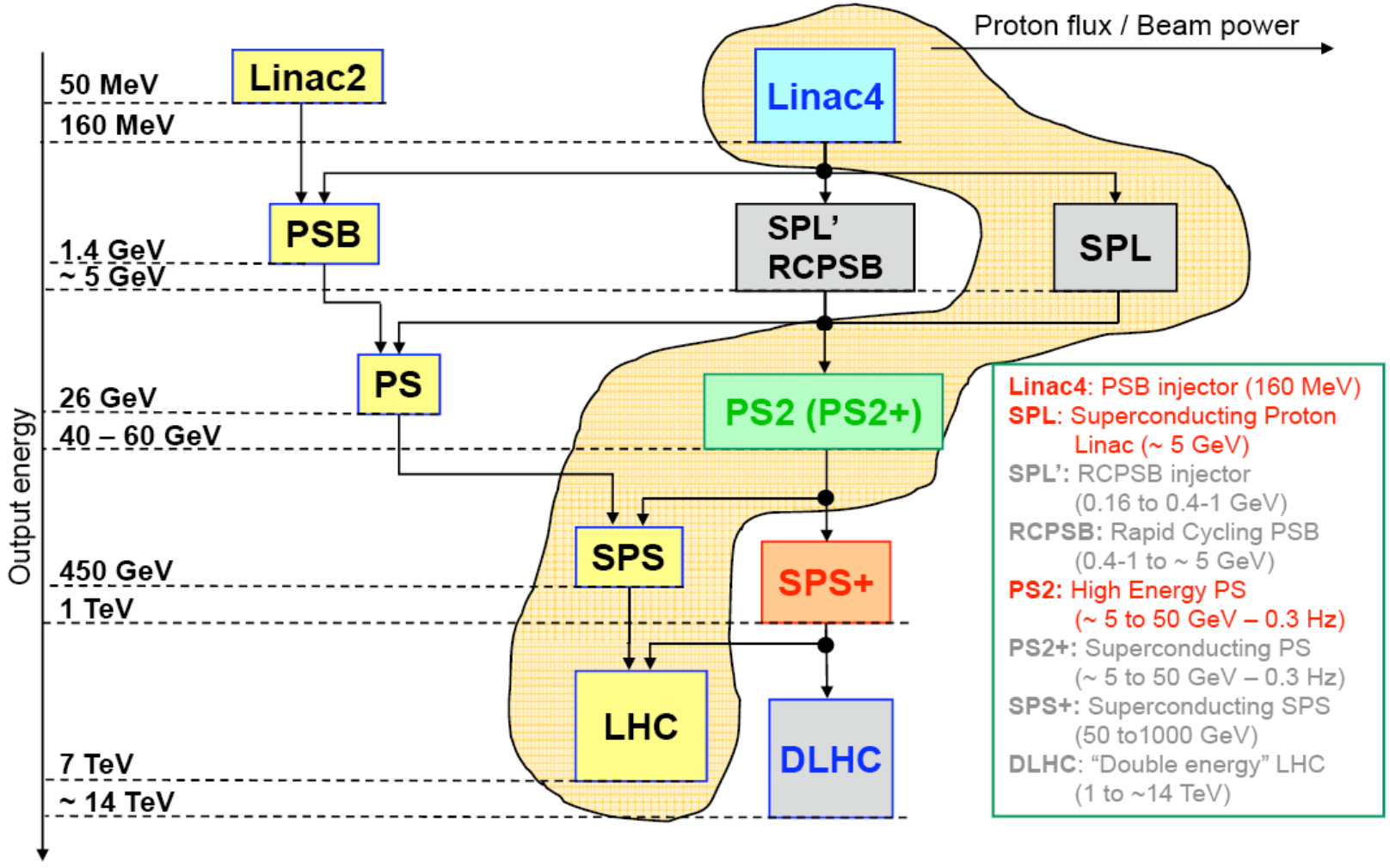
CERN PS2 Upgrade

based on material by M. Benedikt, Y. Papaphilippou, S. Hancock et al.

LHC Injector Upgrade

White Paper Studies for LHC Injector Upgrade

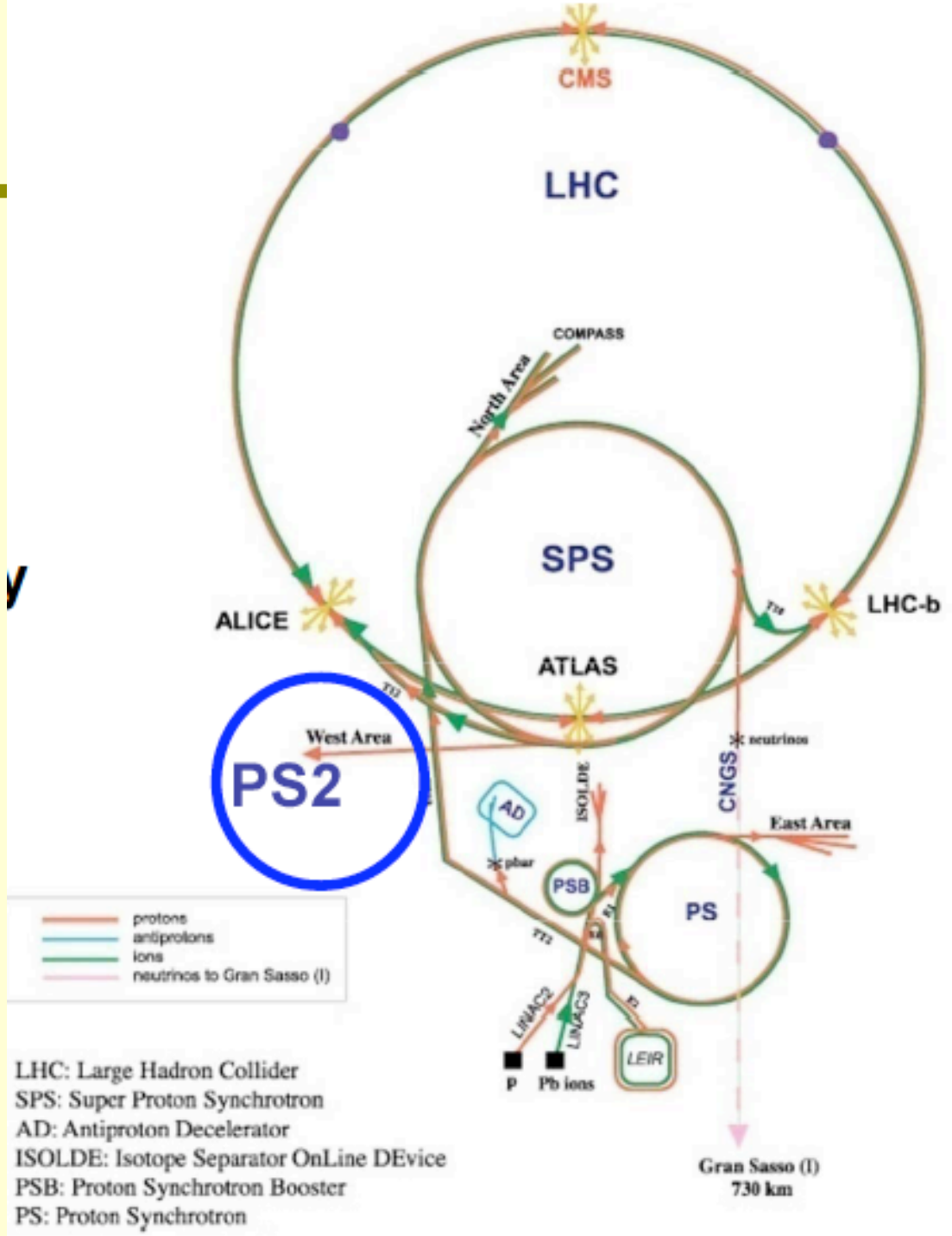


Performance Req'ts

- **Beam brightness for LHC luminosity upgrade:**
  - **Reach twice brightness of the ultimate 25 ns LHC beam (~20% reserve for losses): 4.2×10^{11} per LHC bunch (inst. 1.7×10^{11})**
    - Determines average line density in the machine at injection and therefore the injection energy via incoherent SC tune spread.
- **Significantly higher injection energy into SPS (~50 GeV).**
  - **Injection into SPS well above transition energy**
  - **Reduced space charge at SPS injection**
  - **Smaller transverse emittances and reduced losses**
  - **Potential for long-term SPS replacement with higher energy.**
    - Ejection energy determines PS2 size and magnet requirements
- **As versatile as existing PS**
  - **Protons, ions, high intensity physics beams, slow extraction, etc.**

Machine Size

- Constraints from filling SPS for physics
  - Complete filling of SPS circumference desired for HI FT physics
  - Use island multi-turn extraction scheme, similar to PS (5-turns)
    - Ideal PS2 length 1/5 SPS = 11/5 PS = 2.2 PS.
- Constraints from synchronisation (rf cogging)
  - $N \times h_{PS2} = K \times h_{SPS}$ is needed for correct synchronisation
    - Best candidates are (N, K) = (77, 15) or (77, 16)
    - Where 77/15 is preferred since 5 PS2 are slightly shorter than the SPS.
- Optimum length for PS2 from above arguments
  - PS2 = 15/77 SPS = 15/77 * 11 PS = 15/7 PS.
  - Circumference PS2 = 15/7 PS = 1346.4 m
  - Radius PS2 = 214.3 m
  - h (200MHz SPS) = 4620, h (40MHz SPS) = 924, h (40MHz PS2) = 180



LHC: Large Hadron Collider
SPS: Super Proton Synchrotron
AD: Antiproton Decelerator
ISOLDE: Isotope Separator OnLine DEvice
PSB: Proton Synchrotron Booster
PS: Proton Synchrotron


Linac 4
SPL
96,7
(460)
PROFIL EN LONG - H=1/2000 L=1/1000
COUPE AMORCE SPL - 1/200e
Coupe A-A - 1/100e
Coupe B-B - 1/100e
PS2
TI2
TT10
GOLF
Practice
Foot
Rugby

PS2 Prelim. Parameters

Parameter	unit	PS2	PS
Injection energy kinetic	GeV	4.0	1.4
Extraction energy kinetic	GeV	~ 50	13/25
Max. intensity LHC (25ns)	ppb	4.0×10^{11}	1.7×10^{11}
Max. intensity FT	ppp	1.2×10^{14}	3.3×10^{13}
Max. stored energy	kJ	1000	70
Linear ramp rate	T/s	1.5	2.2
Repetition time (50 GeV)	s	~ 2.5	1.2/2.4
Max. effective beam power	kW	400	60

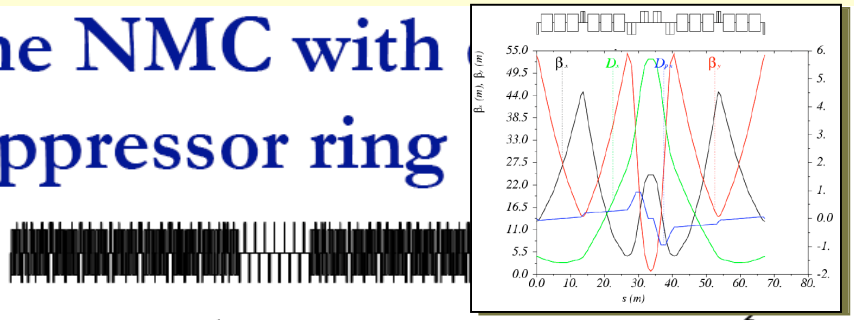
Real or Imag γ_{TR} ?

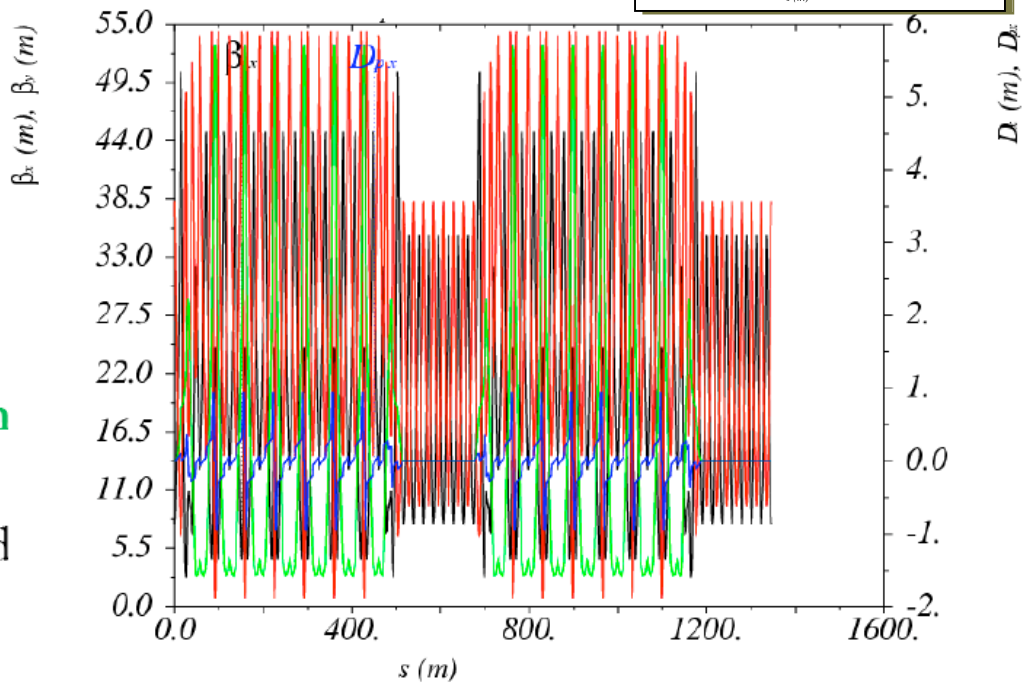
- Real transition:
  - Have to cross without enlarging emittance
    - gtr jumps etc.
  - High enough ns to allow for "rf gymnastics" needed to match bunch shape to SPS
  - Straightforward magnet lattice
- Imaginary transition (=negative α_p)
  - No transition crossing => no emittance issue
  - Don't need rf gymnastics for *p*, maybe for ions
    - Need very high $|\alpha_p|$ to raise ns at extraction if rf gymnastics is wanted
  - > magnet lattice rather complicated

Imag. γ_{TR} Candidate

- γ_t of **19.8i**
- Tunes of **15.75** and **13.75**
- **180** dipoles, **3.3m** long
- **134** quadrupoles in **12 (+ 2)** families of **5** types with max. strength of **0.1m^{-2}**
- Max. beta of **51m** in horizontal and **54m** in the vertical plane
- Dispersion min. of **-1.5m** and max. of **5.7m**
- Chromaticities of **-21** and **-31**
- Total length of **1346.4m**

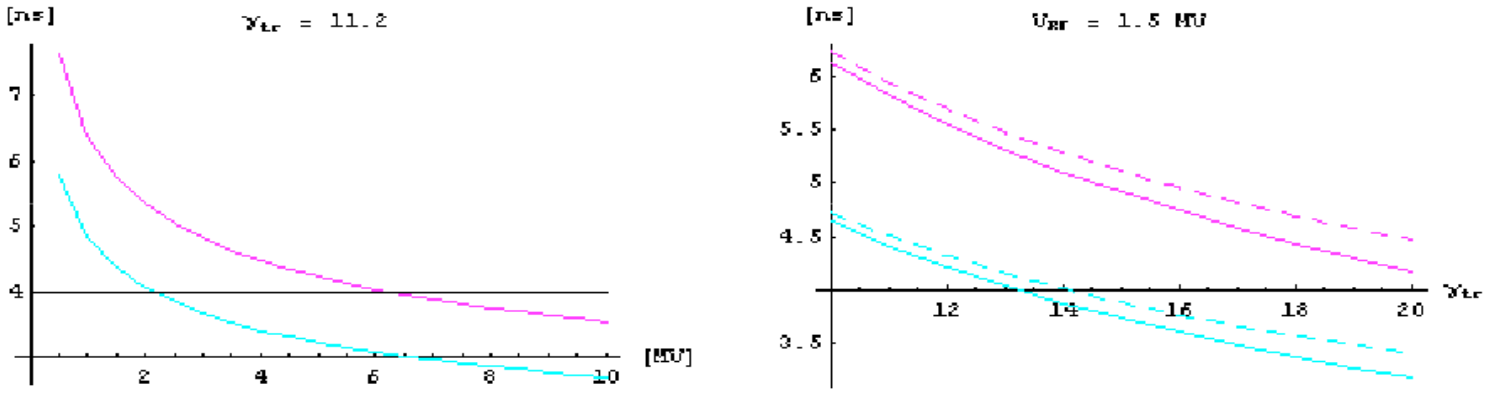
The NMC with suppressor ring



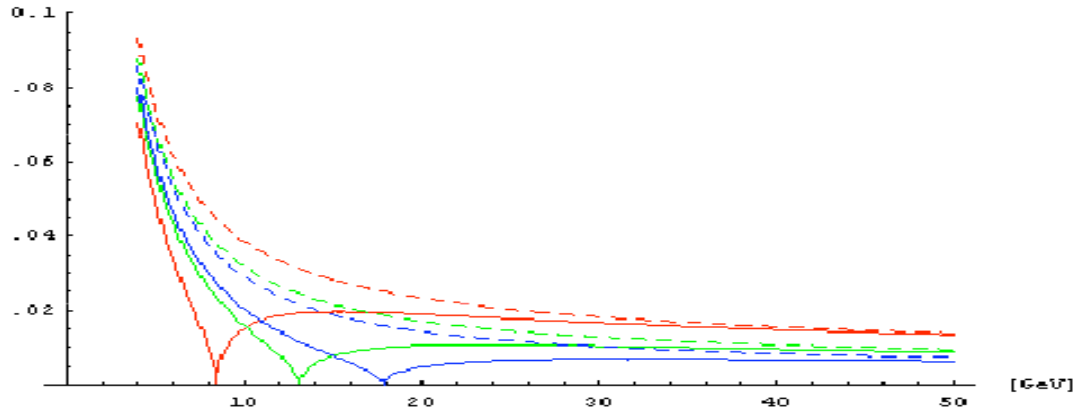


- At the May-29 PS2 internal review:
  - Working decision to pursue imag. γ_{tr}
  - This naturally asks for an rf frequency ≈ 40 MHz
    - natural match to SPS, no need for rf gymnastics
    - but need 20 MHz for ions
      - two rf systems, or one with large tuning range
- Need to settle exact γ_{tr} value
  - I suspect it'll be higher (i30…i100)
    - this defines parameters like ν_s, V_{rf}, bunch length etc.

Longitudinal Parms



Bunch length for matched bunches of 0.35eVs (cyan) and 0.6eVs (magenta) for real (solid lines) and imaginary (dashed lines) values of γ_{tr}.



Adiabaticity factor $\sqrt{(|\eta|/\gamma)}$ versus kinetic energy for protons in the PS2 for real (solid lines) and imaginary (dashed lines) values of γ_{tr} of 10 (red), 15 (green) and 20 (blue).

More Parameters

My evaluation, subject to changes!

Parameter	Unit	LHC(25ns)	FT
γ_{tr}		≈ i10	≈ i10
ppb		4.2E11	7…8E11
l_{bunch}(1.5 MV)	m	≈ 1.6	≈ 1.2
$I_{average}$	A	2.5	3.9
I_{peak}	A	12	26
$\varepsilon_{long,extr}$	eVs	0.6	0.35
ν_s(for 1.5 MV)		0.009	0.009

Where does LARP fit?

- PS2 Design Report due by end of 2010
- CERN interested in getting help
  - resources tight until LHC commissioned
- LARP interested in doing "interesting" work
  - also potential interested in construction work
  - should be collaborative amongst LARP labs
- … need to identify interesting work useful in advancing the PS2 studies

My attempt...

- PS2 Topic 1:
  - Tracking, nonlinearities, space charge, halos, H^- injection, MTE
- PS2 Topic 2:
  - Intensity effects, Instabilities, Impedance
- PS2 Topic 3:
  - Rf System

Topic 1

- H^- Laser stripping-injection R&D (ORNL-SNS, LBNL)
- Injection simulation with imag γ_{tr} lattice, phase-space painting, sp. charge, halo development, … (FNAL? synergy with Project X, LBNL, SNS?)
- Beam collimation: tracking as well as hardware. Crystal collimation?? (SLAC?, FNAL?)
- MultiTurnExtraction (MTE) (BNL interest, synergy with (g-2) expt.@JPARC)
- Imag. γ_{tr} lattice R&D (BNL, SLAC?)

Topic 2

- Impedance evaluation, simulation of components, testing of prototypes (later) (SLAC, LBNL, FNAL)
- Multibunch instabilities, feedback systems, fb kickers (SLAC, LBNL)
- e-Cloud R&D: Vacuum requirements, chamber concepts, tie-in with SPS e-cloud expts. Synergy with Project X & BNL RHIC.

Topic 3

- Rf System
  - New development of a perpendicularly biased 40-MHz cavity with high gradient. Concept originally developed at LANL. FNAL has done some work in that direction for the Booster. This is a very challenging project!
  - LLRF R&D (SLAC ?).